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SERIE: PLANKTON · BIND I

Nr. 4. Ove Paulsen: STUDIES ON THE BIOLOGY OF *CALANUS FINMARCHICUS* IN THE WATERS ROUND ICELAND. WITH 3 PLATES

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STUDIES ON THE BIOLOGY OF *CALANUS FINMARCHICUS*

IN THE WATERS ROUND ICELAND

BY

OVE PAULSEN

WITH 3 PLATES

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Among the plankton organisms of the Norwegian Sea and the northern Atlantic Ocean *Calanus finmarchicus* plays an extraordinarily important part, being the most common of the macroscopic organisms, at any rate amongst those which occur along sea-coasts and in the surface water-layers. It is one of the main food-supplies for larger plankton-eating marine-animals. It has also been known for a long time, being first described in the eighteenth century by the Norwegian Bishop Gunnerus (as *Monoculus finmarchicus*), and both scientific expeditions and practical men, who have visited the northern seas, have observed and mentioned it.

So far as known to me, Gran[1] was the first, who made biological observations on *Calanus finmarchicus*. He separated its different developmental stages and was thus able to follow its growth. He did not know the larval stages however.

Of the results he came to by his studies in 1900 and 1901 the following may be mentioned:

The propagation-period at the northwest coast of Norway is in April—May, and the animals die after propagating. The duration of life, he considers, is different at different places, warmth aids the development, but gives small individuals. — The animals live in autumn in deep-water, in the spring at the surface, whilst in summer the young especially live at the surface.

Calanus finmarchicus is common to the whole of the Norwegian Sea, but is most abundant in the warmer parts, the largest quantities are to be found in the warm stream which runs N. E. along the Norwegian coastal banks.

Damas[2] carried further what Gran had begun. After studying and learning to recognise the larval forms of the copepods (*Metanauplius* and *Nauplius*) he investigated the distribution of all stages of *Calanus finmarchicus* in the Norwegian Sea in May—June 1904. The main result of this investigation is: the great mass of mature *Calanus finmarchicus* are in spring found to the east of the East Icelandic Polar Current, and during the period the eggs are being laid and the larvae hatching, they are carried southwards down towards the Færoes and thence to the northeast along the Norwegian coast. During this transport the adult individuals gradually die and the young grow up, so that from south-west to north-east in the direction taken by the Gulf Stream along Norway, we first meet with the adults, then the larvae and younger postlarval stages, and lastly the older postlarval stages. The development of *Calanus finmarchicus* in the Norwegian Sea proceeds therefore in a circulating current; it is yet unknown, however, how the circle is to be closed towards the north i. e. where the animals live in winter and where the spring's great quantities of mature individuals come from.

That *Calanus finmarchicus* reproduces mainly in the spring is certain, but what are the conditions with regard to it during the summer and the winter? and if its development in the Norwegian Sea proceeds in a circulating current, what are the facts in the seas around Iceland? These questions I

[1] Das Plankton des norwegischen Nordmeeres (Report on Norwegian Fishery- and Marine-Investigations II 1902 Nr. 5). Bergen 1902 p. 56 f.

[2] Notes biologiques sur les Copépodes de la mer Norvégienne. Publications de Circonstance Nr. 22. Copenhague 1905.

endeavoured to get solved, when I visited Dr. GRAN in Bergen in the spring of 1904 and there met DAMAS, who was engaged in his investigation on *Calanus finmarchicus*. Not being a zoologist however, I could not venture to take upon myself the task of separating and distinguishing the larval stages of the copepods, so that the following report will only deal with the postlarval. These have been worked out by GRAN and are also given by DAMAS. — I mention them here, together with the designations I shall use in the following pages:

♂ 5 segments in abdomen, 5 pairs of legs
I 4 — - — , 5 — - — (mature ♀)
II 4 — - — , the foremost small, 5 pairs of legs
III 3 — - — , 5 pairs of legs
IV 2 — - — , 4 — - —
V 2 — - — , 3 — - —
VI 2 — - — , 2 — - —

The stages II—IV are included together as "*juniores*".

The manner in which the investigation was made was to take at hazard 100 specimens of *Calanus finmarchicus* from each sample, and of these to count how many there were in each stage. The results thus express the number of specimens of each stage in percentage. By repeated control-countings I have convinced myself, that the counting of 100 specimens gives a correct picture of the relative quantities of the age-groups in the samples.

There are some sources of error, however. In the first place, the collections have not always been made in the same manner. A part of the material comes from plankton-samples taken by the S.S. "Laura" on its regular post-voyages to Iceland and by the S.S. "Hólar" and S.S. "Skálholt" on their way round Iceland, from one fjord to another. All these samples were taken by means of a deck-pump, which sucks up the water from a depth of ca. 4 m.; the water is then filtered through a plankton-net of Gauze 20. All these samples are poor, the "Hólar' has for example pumped up plankton on the same day and at the same place as I have collected plankton from the "Thor" with plankton-nets at the surface, and I could see from these, for example, that the water might contain many *Calanus finmarchicus* without one being able to get 100 specimens in all in the pumped samples for counting.

A comparison of the samples taken by the "Thor" with Gauze 0 and Gauze 20 shows, that the small stages of *Calanus finmarchicus* (V, VI), escape in great part through the coarse net. As samples were always taken with both nets, I have preferably used those taken by the fine, but as this fishes many times less than the large and its meshes often quickly become stopped up, enough material is not obtained and samples from the coarse net must then be used. This concerns both the horizontal and vertical hauls. Finally, I have used some material gathered by Dr. SCHMIDT in April 1904, partly with the coarse net, partly with the young-fish trawl. In the latter the meshes are even a little coarser than those of the net.

The apparatus used were:	denoted by:
1. Deck-pump, net of Gauze 20.	The name of the ship.
2. Small horizontal net of Gauze 20.	Horiz. net.
3. Apstein's vertical net of Gauze 20.	Ap.
4. Nansen's vertical net, of different sizes, Gauze 20.	Nans. 20.
5. The same, Gauze 0.	Nans. 0.
6. Large horizontal net, Gauze 20 ("Egg-net").	Egg-net.
7. Young-fish trawl.	Young-fish trawl.

As these different methods of fishing cannot well be compared, I have discarded quantitative measurements or countings of the material.

I wish to mention another difficulty in the investigation undertaken. Whilst the investigations from the Norwegian side had a well defined region to explore, an open area, in which the currents are in the main known, this investigation deals with the waters round an island washed by widely different seas, whose currents are scarcely sufficiently well-known. This holds for example for the waters to the south of Iceland. It is of importance to know how the currents run here, in order to understand the biological connection between the Norwegian Sea and the Atlantic Ocean. According to RYDER's[1] current-chart the current running N. E. bends round the south and south-east of Iceland and follows its south coast from east to west, and DAMAS seems to have the same opinion, taking it as probable, that the Nauplii and *juniores*, which have their origin in the seas round the Færoes are carried up from there towards Iceland. But there are facts which indicate, that the current to the south of Iceland, at any rate sometimes, moves from west to east; thus, I have found plankton diatoms at 64° N.L., 11° 45′ W.L. which cannot well have come from other than the waters on the south coast of Iceland. I hope to return to this later on.

To the west of Iceland, the Denmark Straits have their own circulation[2], caused by the warm stream, the Irminger Current, coming from the south along the west coast of Iceland and the cold stream from the north along the east coast of Greenland. To the north of Iceland the cold water from the north meets the warm easterly branch of the Irminger Current[3], and along the east coast of Iceland runs the south-going Polar Current, which takes part in the circulation of the Norwegian Sea.

Thus there are many different current-systems, which can be of importance for the migration and development of an organism such as *Calanus finmarchicus*. To this may be added that a large number of the plankton-samples examined were taken near the coast, that is, in coastal waters, which makes them possibly less comparable with the oceanic samples. But in this connection we must remember, that the neritic plankton-associations are of great importance and interest, as e. g. the rich shoals of herrings, which often visit North Iceland in later summer, feed upon them and especially on great quantities of *Calanus finmarchicus*.

In the following pages we shall deal with the distribution of *Calanus finmarchicus* in the spring, summer and autumn of 1904. In addition to the samples where the countings were made, I have used my own records from the cruise of the "Thor" in 1904 and in a few cases also those of Dr. SCHMIDT.

For the sake of clearness each month's collections are treated separately.

April 1904 (Plate I)

All the stations are marked with black on Plate 1 and therewith signs indicative of the predominant developmental stages of each station as also the serial number from the list. In the latter the predominant percentage in each sample is marked in black type. The numbers in brackets indicate that 100 specimens were not examined in the sample concerned (as there were not so many). A query? on the Chart has the same significance. In the last column "Laura" (or other ships' names in the following lists) indicates that the samples were pumped up and filtered through gauze 20. "Horiz. net" means the small plankton-

[1] Some investigations on the ocean currents in the sea between Norway. Scotland and Greenland. Nautical-Meteorological Annual. 1901. Kjøbenhavn 1902—1904. Kjøbenhavn 1905.

[2] See: M. KNUDSEN: Hydrografi. Den danske Ingolfexpedition I. 1898.

[3] See: M. KNUDSEN: l. c. — J. N. NIELSEN: Contributions to the Hydrography of the waters North of Iceland. Meddelelser fra Kommissionen for Havundersøgelser. Ser. Hydrografi. Bd. I. Nr. 7. København 1905.

Material

A single haul in March by the S.S. "Laura" is included here

No.	Date	N. Lat.	W. Long.	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
	March											
1	19. III	63°44′	22°22′	(2)	(**27**)	(3)	...	...	...	...	.....	Laura
	April											
2	14. IV	60°09′	8°15′	...	**81**	16	2	1	...	...	.....	„
3	15. IV	62°00′	14°54′	1	**73**	17	9	...	...	...	c	„
4	16. IV	62°35′	17°05′	...	(**52**)	(31)	(15)	...	...	...	.....	„
5	16. IV	63°50′	16°31′	1	**94**	2	3	...	...	...	+	horiz. net
6	17. IV	63°26′	20°11′	6	**87**	2	3	1	...	1	c	„
7	19. IV	63°44′	22°35′	...	...	11	**62**	27	...	...	.....	egg-net
8	22. IV	63°23′	9°43′	...	**100**	...	...	...	...	...	.....	horiz. net
9	»	64°49′	23°59′	...	18	**49**	30	3	...	...	.....	egg-net
10	»	65°29·5′	24°30′	...	13	6	**32**	16	22	11	+	horiz. net
11	»	»	»	...	**44**	10	30	16	...	...	.....	egg-net
12	»	»	»	1	**89**	5	5	...	...	...	.....	young-fish trawl ca. 4 m. depth
13	23. IV	66°32′	17°56′	...	**93**	5	2	...	...	...	.....	„
14	24. IV	66°28′	15°48′	1	**98**	1	...	...	...	...	.....	„
15	»	66°17·5′	14°22·5′	...	**77**	16	7	...	...	...	.....	young-fish trawl ca. 25 m. depth
16	»	65°45·5′	14°15′	...	(6)	(4)	(**14**)	(13)	...	...	.....	young-fish trawl ca. 4 m. depth
17	30. IV	63°31′	21°14′	...	35	**51**	11	3	...	...	.....	Laura

net with gauze 20, "egg-net" the large plankton-net with gauze 0. A notion of the relative capacities of these two nets and of the young-fish trawl to catch the different stages of *Calanus finmarchicus* is obtained from Nos. 10, 11 and 12 on the list – three samples taken at the same time with the different apparatus. It appears from these that samples taken by the young-fish trawl have no great value for our investigation, as practically all the smaller specimens escape through the meshes. The egg-net also seems to permit many of the small to escape. The most valuable samples are those taken by gauze 20, even if the possibility is not altogether excluded that some of the adult specimens escape during the slow filtration. On the charts brackets are placed round all the numbers which do not come from samples taken with gauze 20. N. denotes: considerable quantities of Nauplius.

On examining the Chart we find that by far the majority of the *Calanus finmarchicus* in the Atlantic south and south-east from Iceland are adult females, further, these occurred in quantities on the surface of the ocean. At several stations certainly the "Laura" has taken nothing, which might indicate that these copepods are massed together in shoals, but as already mentioned the means of capture were not very good, and negative catches from pumping are therefore not shown on the charts.

Many Nauplii were taken with the adult females (samples 3, 4, 5, 6). Males also occurred though not usually.

The quantities of adult females and Nauplii show that *Calanus finmarchicus* is in full process of propagation in April in the Atlantic south from Iceland, both at the coast and out to sea.

To the west of Iceland the conditions are different, and it seems as if the change began already to the south of Reykjanes. Adult specimens (sample 1) were found here on March 19th, but exactly a month later (sample 7) no adults at all were taken but only *juniores* especially III. About the same time adult females were found somewhat more to the east (No. 6, March 17th) and II (No. 17, March 30th). — I have seen two samples from Faxe Bay, but have not had the opportunity to count them, in both of which was a large number of *juniores* and much smaller quantities of adults. — Samples 9 and 10, from Snefellsnæs and Staalbjerghuk, would probably have the same composition, if they had both been taken with gauze 20, and I thus venture to conclude that stage III has been predominant along the west coast of Iceland in April. Samples 11 and 12, collected at the same time as 10, but with

the egg-net and the young-fish trawl, have no great interest, it is doubtful if we can rightly conclude from the last that the adults were predominant in the deep water.

The April material I have had from the north and east coasts of Iceland is unfortunately very small. I have seen some samples taken on the cruises of the "Hólar" and "Skálholt", one from Isa Fjord, one from Cape North, one from Skagatá, one from Gógurtá, two from Rödehuk, one from Lánganes and one from Papey. They were all taken in the latter half of April and none of them contain more than a single specimen of *Calanus finmarchicus* or very few Nauplii of parentage unknown to me. Of more importance is the information to be gained from Dr. SCHMIDT's journal and collections from his voyage with the "Thor" to the north of Iceland in April. From these I have examined samples taken with the horizontal net (gauze 20) in Isa Fjord, at Cape North, at Rödehuk and at Lánganes, all with negative results, only a few Nauplii were taken at Lánganes. Nor were any copepods (though many Euphausidae) found in deep water in the Isa Fjord with the young-fish trawl (ca. 30 m.); on the other hand, a number of *Calanus finmarchicus* chiefly adults were taken at Grimsey (Nr. 13) and east from Rödehuk (No. 14), at Grimsey along with Euphausidae, east from Rödehuk along with Euphausidae and *Calanus hyperboreus*. Similar conditions were found at Lánganes (No. 14) at a greater depth. From the east coast I have only seen a single poor sample from Kollemuli (No. 15) — in this as is seen *juniores* were predominant.

When I add further that in Dr. SCHMIDT's journal I find the remark "few copepods" both for deep water and surface at some stations off Huna Bay, and that I have made negative hauls off Seydis Fjord, in Röde Fjord and at the Horns, my notes on *Calanus finmarchicus* in April are completed. They may be summarised in a few words: In April, there are many adult *Calanus finmarchicus* and Nauplii at the surface of the sea to the south of Iceland, many *juniores* and Nauplii (Sample 10) west of Iceland likewise on the surface. North of Iceland there are but few adults and probably no *juniores*. Along the east coast of Iceland *Calanus finmarchicus* seems for the most part to be absent.

There is no doubt that the adult *Calanus finmarchicus* in the Atlantic is the old, spawning generation, and it therefore seems to me indubitable that it is the new generation we meet with to the west of Iceland. Where have the parents of the latter lived? Do they come from the ocean to the south of Iceland or do they come from the Denmark Straits, which has its own "basin-water" and its own circulatory movement? The first seems to me the more probable, as we know that water from the Atlantic south of Iceland flows along the west side of the island (Irminger Current). As the animals follow with this current, the old generation gradually dies out and the new grows up. The latter cannot be detected in the few samples taken from these parts; in samples 6, 7, 9 and 10 we see only that the adults are decreasing and the *juniores* take the lead; that No. 9 and No. 10 probably express the same thing in reality has already been mentioned above.

It must also be the old generation which is met with in deep water to the north of Iceland. That some Nauplii (of *Calanus finmarchicus*?) were found at Lánganes and a small number of *juniores* at Kollomuli might be considered as a local propagation, as the current goes just that way, but it is impossible to speak with any degree of certainty as the material is so small.

May 1904 (Plate I)

Nos 1—26 (see p. 8) are samples from the Danish seasonal stations (Da 2—Da 19) between the Færoes and Iceland. Their contents are shown in the "Bulletin des résultats acquis pendant les courses périodiques", 1903—04, May 1904, Supplément; they have also been used by DAMAS and described in his paper mentioned above. Some of the samples unfortunately were spoilt when being forwarded. They were taken for the most part in vertical hauls and are remarkable for the considerable number of males many

Material

No.	Date	N. Lat.	W. Long.	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
1	3	64°58′	11°45′ (Da 17)	1	**66**	18	11	3	1	...	.....	Nans. 0, 230—100 m.
2	»	»	» »	...	(**16**)	(4)	...	(6)	(4)	(3)	+	Horiz.-net
3	4	64°35′	11°45′ (Da 16)	(1)	(**7**)	(3)	(1)	(1)	...	...	.....	Nans. 0, 230—70 m.
4	»	64°12′	11°45′ (Da 15)	12	**76**	7	5	...	...	...	.....	„ 370—175 m.
5	»	»	» »	2	**65**	13	19	1	...	...	.....	„ 160—0 m.
6	»	63°43′	11°45′ (Da 14)	6	**79**	9	6	...	...	...	.....	„ 320—100 m.
7	»	»	» »	...	(**19**)	(3)	...	...	(1)	...	+	Ap. 100—10 m.
8	»	»	» »	3	**89**	4	3	1	...	...	.....	Nans. 0, 70—0 m.
9	»	63°12′	11°45′ (Da 13)	...	**88**	4	5	2	1	...	r	Horiz.-net
10	5	64°05′	9°38′ (Da 11)	12	**58**	13	17	...	...	...	.....	Nansen 0, 300 - 0 m.
11	»	»	» »	(2)	(**16**)	(5)	(8)	(1)	...	...	r	Ap. 150—70 m.
12	»	»	» »	...	(**18**)	(3)	(2)	(1)	(2)	...	.....	Horiz.-net
13	6	64°26	8°37′ (Da 10)	(16)	(14)	(**19**)	(4)	...	...	...	.....	Nans. 20, 400—100 m.
14	»	»	» »	6	**52**	17	24	...	1	...	.....	Nans. 0, 400—0 m.
15	»	»	» »	...	(**35**)	(5)	(28)	...	...	...	+	Nans. 20, 50—0 m.
16	»	63°50′	9°00′ (Da 9)	...	**91**	5	4	...	...	...	.....	Nans. 0, 200—0 m.
17	7	63°03′	9°28′ (Da 8)	(5)	(**14**)	(7)	(3)	...	...	...	.....	„ 450—300 m.
18	»	»	» »	8	**72**	11	8	1	...	...	.....	„ 200—0 m.
19	»	»	» »	...	(**47**)	(3)	...	...	...	...	cc	Horiz.-net
20	»	62°12′	9°56′ (Da 7)	**7**	**84**	5	3	1	...	...	.....	Nans. 0, 700—0 m.
21	8	62°40′	8°44′ (Da 6)	7	**78**	9	6	...	...	...	.....	„ 400—0 m.
22	»	63°08′	7°44′ (Da 5)	4	**61**	12	21	2	...	...	.....	„ 250—0 m.
23	»	»	» »	...	(**8**)	(1)	(1)	...	...	...	c	Horiz.-net
24	9	63°36′	6°20′ (Da 4)	(2)	(**24**)	(7)	...	...	...	...	.....	Horiz.-net
25	»	63°07′	6°20′ (Da 3)	...	(**29**)	(6)	(2)	...	...	...	c	Ap. 80—0 m.
26	10	62°36′	6°20′ (Da 2)	(2)	(**30**)	(14)	(11)	(2)	...	...	.....	Nans. 0, 130—0 m.
27	4	62°54′	8°04′	...	**46**	8	9	12	18	7	c	Laura
28	»	64°17′	11°48′	1	**88**	10	...	1	...	...	.....	Laura
29	5	59°56′	4°06′	1	**83**	6	10	...	...	...	.....	Laura
30	6	64°00′	15°56′	...	**54**	6	4	8	12	16	c	Hólar
31	11	61°06′	8°30′	8	15	**34**	28	15	...	...	.....	Nans. 0, 90—0 m.
32	»	»	»	1	6	14	**40**	31	8	...	.....	Horiz.-net
33	14	61°30′	6°40′	...	(17)	(**28**)	(22)	(6)	(5)	...	r	Horiz.-net
34	16	62°05′	6°00′	...	**36**	2	16	30	16	...	.....	Egg-net
35	»	»	»	...	(**26**)	(3)	(15)	(15)	(10)	...	.....	Horiz.-net
36	»	62°05′	5°48′	...	**92**	1	6	1	...	...	r	Horiz.-net
37	»	62°05′	4°30′	...	7	1	19	**30**	29	14	+	Horiz.-net
38	»	62°05′	4°10′	1	3	...	...	17	21	**58**	+	Horiz.-net
39	22	61°16′	9°35′	...	**94**	...	2	4	...	...	.....	Egg-net
40	»	61°30′	13°30′	...	8	4	19	**40**	25	4	.....	Egg-net
41	24	63°05′	15°28′	...	**53**	2	21	5	...	...	r	Horiz.-net
42	»	63°26′	16°00′	...	**41**	16	18	19	3	3	+	Horiz.-net
43	»	63°39′	16°20′	...	**97**	3	...	...	...	...	.....	Young-fish trawl ca. 5 m. depth

of them contain. These seem to occur in greatest quantity in samples taken deep down, a fact to which I will return later. On the other hand, the Nauplii are represented in the hauls right to the surface.

The samples from the seasonal cruises show, as we already know from DAMAS' paper, that the waters between the Færoes and Iceland are in May rich in adult individuals of *Calanus finmarchicus* and of Nauplii, this region being essentially one of the spawning places of the species. The only stations which are exceptions from this are Da 18 and Da 19 (lying between Da 17 and Iceland), denoted by a spot on the Chart. These stations, which lie in the East Icelandic Polar Current, show only single specimens of *Calanus finmarchicus* and Nauplii.

East from the Færoes considerable quantities of *juniores* and Nauplii were found, i. e. the new generation of the year (Nos. 33—38).

West from the Færoes (Nos. 31, 32, 39) and from the stations mentioned right to Iceland (Nos. 40, 41, 42), the conditions cannot be understood properly from the present material, we find sometimes *juniores*, sometimes adults and sometimes mixtures of both.

With regard to the coasts round Iceland I have no samples for May 1904 which can throw light on the occurrence of *Calanus finmarchicus*. I have seen some May samples from the cruises of the "Hólar" and "Skálholt" which contain but few or no Calanus. There were two from Snæfellsnes, two from Staalbjærg Huk, three from Isa Fjord, three from Cape North, three from Skagatá and two from Gjögurtá. I find the following notes in my journal:

27th May:	64°19′ N.;	14°32′ W.	Egg-net	a few	*Calanus finmarchicus*,	*juniores*	
30th »	65°29′ N.;	13°32′ W.	»	no	»	»	
» »	»	»	Young-fish trawl, ca. 20 m depth . . .	no	»	»	
» »	65°47′ N.;	14°10′ W.	Young-fish trawl, surface	no	»	»	
» »	»	»	Young-fish trawl, ca. 70 m. depth . . .	a few	»	»	mature

Further, some mature specimens were taken to the south of Langanes on the surface, and some specimens on whose age I have no notes to the north of Langanes and at two westerly stations.

As the investigations here along the east and north coasts were for a great part made with the young-fish trawl, which is a very good fishing apparatus, it may be said with certainty that, in May whereas the Atlantic and the waters between the Færoes and Iceland are rich in *Calanus finmarchicus* the waters on the east and north coasts of Iceland are poor. Of the west coast we know almost nothing.

As the May conditions to the south of Iceland have considerable interest especially in regard to the biological relations between the Norwegian Sea and Atlantic Ocean — as is also noted by Damas — I have also examined my May 1905 material for *Calanus finmarchicus*.

The results of the seasonal cruises for 1905 are not shown here, they gave a similar picture to that for 1904: adults everywhere in quantities, males chiefly in deepwater, Nauplii chiefly on the surface. On the other hand, some investigations made on the voyage of the "Thor" from Ingolfs Höfde (Iceland) to the Hebrides may be mentioned. Unfortunately they were partly spoilt by bad weather.

The various stages are indicated on Chart 2 within squares so that they can readily be distinguished from the 1904 samples.

Material (May 1905)

No.	Date	N. Lat.	W. L.	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
43	23	64°30′	14°20′	(4)	(7)	(**10**)	(5)	. . .	. . .	. . .	. . . . .	Egg-net
44	26	63°21′	16°22′	. . .	5	21	**44**	16	8	6	r	Nans. 20, 40—0 m.
45	»	»	»	. . .	. . .	4	45	**51**	. . .	. . .	. . . . .	Egg-net
46	»	63°07′	16°12′	. . .	2	31	**58**	6	3	. . .	r	Nans. 20, 300—62 m.
47	»	»	»	. . .	. . .	2	20	**32**	32	14	c	Nans. 20, 40—0 m.
48	»	»	»	. . .	. . .	7	14	22	**37**	20	c	Horiz.-net
49	27	62°15′	13°48′	. . .	13	6	13	**35**	27	6	. . . . .	Egg-net
50	»	»	»	. . .	(6)	(4)	(1)	(8)	(7)	(1)	+	Horiz.-net
51	28	61°50′	11°38′	. . .	. . .	23	**32**	32	10	3	+	Nans. 20, 50—10 m.
52	»	»	»	. . .	. . .	33	**35**	29	3	. . .	. . . . .	Egg-net
53	»	»	»	. . .	. . .	(17)	(16)	(**18**)	(5)	(1)	c	Horiz.-net
54	»	61°11′	11°00′	. . .	. . .	16	26	**37**	20	1	. . . . .	Egg-net
55	»	»	»	. . .	. . .	(13)	(18)	(14)	(7)	. . .	+	Horiz.-net
56	29	60°43′	10°42′	. . .	. . .	. . .	7	**57**	36	. . .	. . . . .	Egg-net

It will be seen that all these samples have been collected at the end of May, whilst the samples from the seasonal cruises mentioned above were from the beginning of this month. This difference in time has perhaps however no significance. All the samples No. 43—56 consist almost exclusively of *juniores*. If the Calani had originated in the neighbourhood of the Færoes and if the water with the Calani had moved from south northwards (or rather from south-east to north-west) towards Iceland, the northern samples must, as is maintained by DAMAS, contain older individuals than the southern. Of this there is no sign; if we go from No. 56 towards the north-west we find the following stages to be predominant on the surface: IV, IV, III, IV, V, IV. In deep water the individuals are usually larger. Many Nauplii are found almost everywhere.

This series of observations seems rather to indicate that the *juniores* taken had originated in the same waters in which they were found. We also know from April and May 1904 that quantities of mature individuals were then found in the Atlantic to the south of Iceland.

June 1904 (Plate II)

Material

No.	Date	N. Lat.	W. L.	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
1	2	66°17′	21°14′	...	3	5	25	**30**	30	7	.....	Egg-net
2	»	61°16′	11°06′	...	(3)	(9)	(**18**)	(15)	(2)	...	.....	Laura
3	»	66°20′	23°31′	...	14	13	**46**	25	2	...	.....	Egg-net
4	»	»	»	...	10	14	**41**	26	9	...	.....	Nans. 0, 130—20 m.
5	»	65°23′	24°14′	...	(**47**)	(11)	(5)	....	...	...	.....	Skálholt
6	»	66°05′	23°42′	(1)	(15)	(8)	(15)	(8)	(4)	...	.....	Egg-net
7	»	61°49′	13°17′	...	1	9	**44**	32	12	2	.....	Laura
8	3	64°40′	22°56′	...	(**26**)	(19)	(14)	...	...	...	.....	Skálholt
9	»	62°24′	15°32′	1	**31**	12	21	7	19	9	.....	Laura
10	6	63°29′	20°13′	...	19	**47**	28	4	2	...	.....	Hólar
11	13	66°20′	23°31′	...	**61**	19	10	10	...	...	.....	Egg-net
12	»	66°19′	23°27′	1	**65**	33	1	...	...	...	.....	Young-fish trawl, ca. 50 m. depth
13	17	65°52′	23°58′	9	**74**	17	...	...	...	...	.....	„ „ „ 5 m. „
14				35	**48**	17	...	...	...	...	.....	„ „ „ 25 m. „
15	»	65°53′	24°45′	41	**43**	16	...	...	...	...	.....	„ „ „ 5 m. „
16	»	»	»	**46**	28	26	...	.	...	...	.....	„ „ „ 35 m. „
17	18	65°52′	25°32′	2	**69**	28	1	...	...	...	.....	„ „ „ 5 m. „
18	»	65°50′	26°53′	...	5	6	12	19	**37**	21	.....	Nans. 0, 90—0 m.
19	»	»	»	5	**50**	43	2	...	...	...	.....	Young-fish trawl, ca. 70 m. depth
20	»	63°35′	21°14′	1	...	4	14	10	23	**48**	.....	Laura
21	»	63°04′	17°23′	...	(9)	(23)	(**53**)	(7)	...	...	.....	„
22	19	62°14′	13°10′	...	...	3	(**17**)	(5)	(3)	...	.....	„
23	20	61°20′	5°28′	...	...	(6)	(**34**)	(3)	...	...	.....	„
24	26	65°29′	24°35′	22	23	**36**	16	3	...	...	.....	Egg-net
25	»	»	»	34	**56**	10	...	...	...	...	.....	Young-fish trawl, ca. 5 m. depth
26	27	65°10′	24°05′	3	**56**	41	...	...	...	...	.....	„ „ „ 40 m. „

In the southern waters in June the *juniores* are predominant, as we see from the collections (No. 2, 7, 9, 10, 20, 21, 22, 23) of the "Laura" and "Hólar", the only exception being No. 9, though even in this sample there are many *juniores*, only the mature individuals show here a small maximum. That the "Laura" was able to collect so many *Calanus finmarchicus* as it did indicates that the southern waters were rich in this species.

From the western side we have a doubtful sample (No. 8) from Faxe Bay, but a large number from the waters off the north-west of Iceland. Enormous quantities of *Calanus finmarchicus* were living there in June. Apart from the samples taken with the young-fish trawl we find from samples 3, 4, 5,

6, 11, 18, 24, that the *juniores* formed the preponderating portion, — some samples however (5, 11) consist mostly of adults, and I consider it probable that these belong to the new generation as they occur along with a number of *juniores* most of which are in the larger stages.

Sample No. 24 taken on the surface at Staalbjærg Huk is remarkable, as almost half are adults and of these again the half are males. With this may be classed Nos. 13, 14, 15, 16, 17, 19, 25, 26 all taken with the young-fish trawl at different depths. These samples were large and in addition to varying quantities of *Calanus finmarchicus* contained: jelly fishes, larvae of crabs and young of Euphausidae. *Calanus* occurs in greatest quantities in Nos. 12, 15, 16, 17. These young-fish trawl samples contain only specimens of stage II of the *juniores*, younger stages pass through the meshes. From our other hauls we may conclude that the *juniores* would have been in the majority if they could have been taken. As the Table shows, the adults are now predominant and in many cases just as many males as females are present. The females do not seem to me to differ from the mature females of April and May, they are not any clearer or more transparent than these (see DAMAS l. c. p. 7). The presence of many adult males would also seem to be meaningless if the females were not mature.

I imagine that the young-fish trawl samples, if they had been taken with the egg-net, would have appeared somewhat as No. 24, that there would therefore have been a maximum near I and that the curve would have descended evenly from this maximum to the right. According to this line of reasoning, the adult *Calanus finmarchicus* N.W. of Iceland would belong to this year's generation and a number of them are already mature and spawn in June.

In several samples (not given in the Table) taken on the north-west coast with gauze 20 no small quantities of *Nauplii* were found.

It was shown above that only a few *Calani* were found off the eastern part of Iceland's north coast in the last days of May. The same holds for the central part of the north coast in the first days of June: off Skialfandi Bay there were no *Calani*, neither on the surface nor in deep water (some Euphausidae in deep water, crab larvae at the surface); at 66°16′ N., 19°22′ W. some few *Calanus finmarchicus* on the surface but none in deep water (here however Euphausidae and a few *Calanus hyperboreus*. But on the same day (June 2nd) ca. 45 miles more to the west (Sample 1) many *Calanus finmarchicus* were taken, especially on the surface but also in deep water (mostly I).

35 miles more to the westward (at Cape North) Dr. SCHMIDT found the fry of the cod of the same year, in all probability carried up here by the Irminger Current from the southern waters along the west coast of Iceland. No fry of the cod were found in June at any of the more easterly stations on the north coast of Iceland.

I believe that the small *Calanus finmarchicus* of sample No. 1 likewise originated on the southern (or western?) coast and that up to the beginning of June the Irminger Current carried them as far as the stations mentioned but no further.

In this connection the accompanying hydrographic conditions at North Iceland will be of interest. In the paper of J. N. NIELSEN cited above we find the conditions at the end of May and beginning of June given in Section II (from Langanes to Ønundar Fjord) and its text, a summary of which is given (p. 15) in the following words: "the surface temperature has risen with 2 degrees on an average since the measurings in April, but as to the eastern part this higher temperature is only found in a thin layer nearest the surface, and beneath we still find the lower temperature answering to the state in winter, that is, here we have still the cooled volumes of water in winter near north Iceland. In the western part of the section the rise of temperature, however, is of greater importance, as it has the same vatue to the very bottom, and this means here a supply of quite new volumes of water from the Denmark Strait. The salinity is almost unchanged excepting a lower value in the surface, arising from a mixture with the coast water, which is now supplied in ampler quantities".

It is in this warmer western part that considerable quantities of *Calanus* were found whilst the colder eastern part was much poorer. We thus see that the hydrographical and biological conditions correspond with one another.

From the east coast I have no samples for June; there is one sample from Papey (June 4th) from the voyages of the "Hólar" and 2 from Langanes (June 18the and 27th), but quite without *Calanus*.

The conditions in June as regards *Calanus finmarchicus* may be summed up as follows:

To the south and west of Iceland there are great quantities, mainly *juniores*, — west of Iceland considerable quantities of adults both ♂ and ♀ (the same condition might perhaps have been found in the south if the waters there had been investigated with the young-fish trawl). On the western part of the north coast of Iceland, where the water is warmer, many *juniores* were also found, on the eastern part, where the water is colder, few or none.

July 1904 (Plate II)

Material

No.	Date	N. Lat.	W. Long.	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
1	2	63°46′	22°56′	...	6	39	**48**	7	...	...	.....	Egg-net
2	»	»	»	...	15	**44**	41	...	...	...	.....	Nans. 0, 150—0 m.
3	»	66°10′	20°09′	...	...	13	30	**35**	22	...	.....	Skálholt
4	7	66°29′	22°22′	...	2	4	23	**43**	24	4	+	»
5	8	63°43′	22°22′	...	37	**39**	20	4	...	...	.....	Egg-net
6	»	63°32′	21°30′	3	12	**84**	1	...	...	...	....	Young-fish trawl, ca. 5 m. depth
7	9	63°08′	21°30′	8	7	**75**	10	...	...	...	.....	Nans. 0, 600—240 m.
8	10	61°04′	5°08′	...	...	23	**59**	14	4	...	+	Laura
9	»	61°32′	17°57′	...	**98**	2	...	...	...	...	.....	Young-fish trawl, ca. 35 m. depth
10	11	62°06′	8°50′	...	4	**85**	11	...	...	...	.....	Laura
11	»	61°52′	6°26′	...	1	**81**	15	3	...	...	.....	»
12	»	61°30′	17°08′	...	**41**	34	19	6	...	...	.....	Egg-net
13	12	63°25′	20°03′	...	**44**	7	21	28	...	...	.....	»
14	17	66°26′	14°30′	...	2	21	66	9	2	...	+	Hólar
15	20	65°30′	13°30′	...	...	...	...	45	**57**	1	.....	Egg-net
16	»	66°17′	14°27′	...	...	23	**73**	3	1	...	.....	»
17	»	66°26′	14°30′	...	...	13	**75**	12	...	...	.....	»
18	»	66°33′	16°31′	...	...	7	**79**	14	...	...	.....	»
19	21	66°16′	17°05′	...	...	1	**84**	15	...	...	.....	»
20	»	66°03′	17°23′	...	...	12	**73**	15	...	...	.....	»
21	22	67°11′	17°17′	...	1	...	12	**80**	7	...	.....	»
22	»	66°52′	18°10′	...	...	5	**90**	5	...	...	.....	»
23	23	66°15′	12°13′	...	...	...	8	**87**	15	...	.....	»
24	»	66°11′	12°13′	...	22	**71**	5	2	...	...	.....	Young-fish trawl, ca. 100 m. depth
25	»	66°33′	16°31′	...	1	19	**59**	20	1	...	c	Hólar
26	24	66°12′	18°15′	...	...	...	**60**	33	7	...	c	»
27	25	66°33′	16°31′	...	(1)	(13)	(**49**)	(14)	(11)	...	cc	»
28	26	66°26	14°30′	...	...	34	**61**	3	...	...	c	»
29	28	65°30′	13°30′	...	...	2	13	83	2	...	.....	Egg-net
30	30	64°52′	13°22′	...	2	9	23	**66**	...	...	.....	»

Great quantities of *Calanus finmarchicus* occur like clouds in the southern waters in July. On the western part of the south coast we find great masses and the same holds far to the south between 61° and 62° N. L. None occur (see Plate II) at several intervening stations examined almost at the same time. At the southerly stations mentioned they occur sometimes in deep water sometimes at the surface. Close under the south coast of Iceland we find none, it is as if the Calani shunned the thick masses of diatoms which make the water here quite brown.

Nauplii occur almost everywhere. From Nos. 1, 2, 5, 6, 7, 9, 10, 12, 13 we see that stages II and

I (mature individuals) are the most abundant. Males are present in Nos. 6 and 7, the latter from a considerable depth. Unfortunately I have only seen a few samples taken with the young-fish trawl, otherwise I might possibly have found more males.

This year's generation has thus had a rapid growth in the warm Atlantic waters south from Iceland.

From western waters I have no July samples containing *Calanus finmarchicus*; the "Skálholt" has collected samples without Calani at the following places and times: Snæfellsnes July 14th, July 23rd (Nauplii), Staalbjerg Huk July 10th, July 26th, Isa Fjord July 2nd (Nauplii), July 29th.

In the waters north of Iceland enormous quantities of *Calanus finmarchicus* occurred in July. In this month the "Thor" was not at the westerly north coast, from which I have only two samples (No. 3 and 4) taken by the "Skálholt". They both contain principally *juniores* in stage IV and practically no adults. From the many samples examined from the easterly north coast (Nos. 14, 17—22, 25—28), it appears clearly that the *juniores* of stage III are predominant whilst we still meet practically no adults. Nauplii occur everywhere at the north coast often in enormous quantities. As I usually mention the occurrence of the Nauplii in quantities in the tables and on the charts I have also done so with these though they do not belong to *Calanus finmarchicus*. Dr. Damas has kindly determined them for me, they belong to species of Oithona.

The pelagic life here at North Iceland was very rich in July. In addition to the great quantities of *Calanus finmarchicus*, there were on the surface many jelly-fishes (*Cyanea capillata, Margelis, Thaumantias, Beroë*) and of other copepods frequently *Microsetella atlantica, Pseudocalanus elongatus, Oithona similis, Acartia*, as also larvae of cirripedes and decapods especially of crabs, further *Evadne, Hyperia galba, Parathemisto oblivia, Euthemista compressa*, and not least fish young, amongst others, of cod and haddock which born to the south of Iceland have now in quantities been carried round the western coast into the northern waters. In the deep water also the life was rich, in ca. 200—400 m. quantities occurred of *Calanus hyperboreus, Euchaeta norvegica, Chiridius tenuispinus, Parathemisto oblivia, Conchoecia maxima, Boreophausia inermis, Nyctiphanes norvegicus, Thysanoëssa longicaudata* etc.

Regarding the hydrographical conditions the following may be quoted from Nielsen's paper (p. 17 et seq., section V and VI): along the coast the surface water is fresh (33—34‰) and over 7° in warmth, the bottom water somewhat salter and of 3—4° temperature. Far out to sea the surface water is salter (between 34 and 35‰), but still warm whilst deep down the water is still salter but cold.

The breadth of the eastgoing Irminger Current is given at ca. 60 miles and its depth to ca. 300 meters.

Quantities of herring were taken on the north coast of Iceland when the "Thor" was there. I examined the stomachs of 24 herring taken at Husavík and of ca. 35 cm. in length. The stomach was empty in 6; 5 others contained *Calanus finmarchicus*, often in great quantities, and also crab larvae, young of sandeels (*Ammodytes*), *Podon sp.*, decapod larvae, remains of fishes; 9 contained fishes especially young of sand-eels and 3 remains of indeterminable crustacea.

It thus appears that *Calanus finmarchicus*, here as elsewhere, is an essential part of the food of the herring. I shall return to the herring later.

To the east of Iceland also, the waters contained many *Calanus finmarchicus* in June (Nos. 15, 16, 23, 24, 29, 30). They seem to be smaller than north of Iceland, stage IV being predominant here. But few Nauplii were found.

Summarising the conditions in July we find, that *Calanus finmarchicus* has increased more in the south of Iceland than in the north and that the individuals on the easterly north coast are larger than those on the westerly north coast on the one side and than those on the east coast on the other.

As there are practically no Calani on the greater part of the north coast at the end of May and beginning of June and as NIELSEN (l. c.) has shown with certainty, that the water here is renewed from the west, we are entitled to conclude that the large quantity of Calani on the north coast as also the young of the cod have come with the Irminger Current from the west. And if we can rely upon our two samples from the western part of the north coast giving a reliable picture of the conditions there, we have here the same case as has been shown by DAMAS for the Norwegian Sea, namely, the individuals carried furthest by the current are the oldest and largest.

But as mentioned, the opposite is the case with the Calanus we have found on the east coast of Iceland: they are smaller than their neighbours towards the west.

The rapidity of flow of the eastern branch of the Irminger Current is given by RYDER and by NIELSEN at ca. 6 miles per day, consequently there is nothing against the eastern Calani being carried from the western part of the north coast to the east coast in a month and this is also strengthened by the fact that Dr. SCHMIDT found the young of the cod to the south of Langanes on June 20th.

That the Calani of the east coast are smaller than those which follow after them may be explained by the circumstances, that as they have been the whole time carried forward in advance they have thus constantly experienced colder water for their development than those developed later. They should therefore be the oldest though the smallest. We have also seen in April and June, that the Calani in advance were small (see Plate 1 and 3). That the individuals which developed early have really had colder water than the later can be represented by taking the highest and lowest observed surface-temperatures[1] on the south, west, north and east of Iceland in April, May, June and July.

	South Iceland		West Iceland		North Iceland		East Iceland	
April	5·9°	7·8°	1·9°	5·5°	1·0°	1·7°	0·4°	1·7°
May	6·1°	9·5°	3·0°	7·6°	1·3°	3·0°	1·0°	2·1°
June.	7·3°	11·2°	6·8°	10·8°	4·8°	8·4°	3·5°	5·9°
July	7·7°	12·4°	9·0°	12·1°	6·3°	10·9°	5·6°	9·8°

The first Calani developed (A) are considered to have been born in April in the southern waters, to have been carried in May along the western coast, in June along the northern coast and are to be found in July on the east coast. The later (B) are considered to have been born on the south coast in May, have passed the west coast in June and are found to the north of Iceland in July.

	A				B			
	Min.	Max.	Average		Min.	Max.	Average	
April	5·9°	7·8°	6·8°	south	April	»	»	»
May	3·0°	7·6°	5·3°	west	May	6·1°	9·5°	7·6° south
June	4·8°	8·4°	6·6°	north	June	6·8°	10·8°	8·8° west
July	5·6°	9·8°	7·7°	east	July	6·3°	10·9°	8·6° north

We see that the average has been considerably higher for those born later.

August 1904 (Plate III)

Nos. 1—58 are samples from the seasonal stations as published in the Bulletin des résultats acquis, Août 1904. In the present table only the hauls are included which contain *Calanus finmarchicus* in so great quantities, that counting could give usable numbers. Surface hauls were made at all stations but almost all of these are omitted here. The surface has thus in general been thinly populated with Calanus,

[1] Surface temperature of the sea. Nautical meteorological Annual 1904. Published by the Danish Meteorological Institute, Kjøbenhavn 1905.

Material

No.	Date	N. Lat.	W. Long.	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
1	2	62°36′	6°20′ (Da 2)	..	5	6	**42**	42	5	...	+	Nans. 0, 120—0 m.
2	»	63°06′	6°20′ (Da 3)	...	4	**68**	27	1	...	...	.....	Ap. 1600—500 m.
3	»	»	» »	2	4	**54**	10	18	11	1	+	Nans. 0, 300—0 m.
4	»	»	» »	...	(7)	(**28**)	(9)	(24)	(9)	(3)	.....	Ap. 200—0 m.
5	3	63°36′	6°20′ (Da 4)	...	(3)	(**32**)	(26)	(2)	...	...	.....	„ 400—125 m.
6	»	»	» »	...	...	14	**52**	27	6	1	.....	„ 50—0 m.
7	»	63°53′	6°10′ (Da 4A)	...	7	**47**	43	3	...	...	.....	Nans. 0, 1600—500 m.
8	»	»	» »	...	...	24	**76**	...	...	...	.....	„ , 400—0 m.
9	»	»	» »	...	...	(2)	(**20**)	(5)	...	...	.....	Ap. 50—0 m.
10	»	63°10′	7°31′ (Da 5)	...	2	**78**	20	...	...	...	.....	Nans. 0, 900—450 m.
11	»	»	» »	...	1	**84**	7	7	1	...	.....	Ap. 400—250 m.
12	»	»	» »	2	1	**58**	11	22	6	...	.....	Nans. 0, 400—0 m.
13	»	»	» »	...	1	13	2	28	**34**	22	+	Ap. 100—0 m.
14	4	62°40′	8°44′ (Da 6)	...	2	**84**	12	1	1	...	.....	„ 470—400 m.
15	»	»	» »	1	2	**44**	10	34	8	1	.....	Nans. 0, 450—0 m.
16	»	»	» »	...	3	11	20	**50**	11	4	c	Ap. 300—0 m.
17	»	62°12′	9°56′ (Da 7)	1	9	23	25	**34**	8	...	.....	Nans. 0, 300—0 m.
18	»	»	» »	...	...	(5)	(1)	(2)	...	...	.....	Horiz.-net
19	5	63°03′	9°28′ (Da 8)	...	...	**87**	13	...	...	...	.....	Nans. 0, 500—280 m.
20	»	»	» »	...	6	**50**	16	27	1	...	.....	Ap. 200—80 m.
21	»	»	» »	...	3	23	4	**45**	25	...	.....	Nans. 0, 200—0 m.
22	»	»	» »	...	...	(5)	...	(16)	(**41**)	17	+	Ap. 50—0 m.
23	»	63°50′	9°00′ (Da 9)	...	1	**97**	2	...	...	...	.....	„ 700—400 m.
24	»	»	» »	...	1	**96**	2	1	...	...	.....	Nans. 0, 700—500 m.
25	»	»	» »	5	15	**36**	12	15	17	...	.....	„ , 300—0 m.
26	6	64°26′	8°37′ (Da 10)	7	14	**74**	6	1	...	...	.....	„ , 300—120 m.
27	»	»	» »	1	...	28	**61**	9	1	...	... ...	„ , 100—0 m.
28	»	»	» »	...	...	(9)	(**32**)	(5)	...	...	.....	Horiz.-net
29	»	64°05′	9°38′ (Da 11)	...	...	**30**	(4)	...	...	...	.....	Ap. 600—320 m.
30	»	»	» »	...	...	**93**	7	...	...	...	.....	Nans. 0, 600—320 m.
31	»	»	» »	1	22	13	**28**	14	22	...	+	Ap. 150—0.
32	»	»	» »	1	2	**63**	17	9	7	1	.....	Nans. 0, 150—0 m.
33	»	63°40′	10°38′ (Da 12)	4	1	23	17	**45**	9	1	... ...	„ , 300—190 m.
34	»	»	» »	...	1	3	18	**52**	25	1	.....	Ap. 150—0.
35	»	»	» »	...	1	4	18	**60**	14	3	.....	Nans. 0, 150—0.
36	»	»	» »	...	...	1	13	**61**	21	4	.....	Horiz.-net
37	7	63°12′	11°45′ (Da 13)	...	...	(**37**)	(10)	...	...	...	.....	Ap. 400—225 m.
38	»	»	» »	...	1	**78**	16	4	1	...	.....	Nans. 0, 400—225 m.
39	»	»	» »	...	...	3	28	**51**	13	5	+	Ap. 150—0 m.
40	»	»	» »	...	...	2	40	**50**	8	...	.....	Nans. 0, 150—0 m.
41	»	63°43′	11°45′ (Da 14)	(3)	(2)	(**16**)	(3)	(1)	...	...	.....	Ap. 300—140 m.
42	»	»	» »	5	13	**79**	2	1	...	...	.....	Nans. 0, 300—140 m.
43	»	»	» »	...	...	(**27**)	(10)	(12)	...	...	+	Ap. 100—0 m.
44	»	»	» »	...	1	**44**	36	19	...	...	.....	Nans. 0, 100—0.
45	»	64°12′	11°45′ (Da 15)	(1)	(1)	(**38**)	(9)	...	...	...	.....	Ap. 275—150 m.
46	»	»	» »	1	4	**67**	21	7	...	..	.....	Nans. 0, 275—150 m.
47	»	»	» »	...	(1)	(2)	(6)	(**42**)	(4)	(2)	c	Ap. 100—0 m.
48	»	»	» »	1	2	12	15	**52**	17	1	.....	Nans. 0, 100—0 m.
49	8	64°35′	11°45′ (Da 16)	...	12	**62**	19	7	...	...	.....	„ , 330—250 m.
50	»	»	» »	(1)	(2)	(7)	(2)	...	...	...	.....	Ap. 250—180 m.
51	»	»	» »	3	10	**56**	22	8	1	...	.....	Nans. 0, 250—180 m.
52	»	»	» »	...	...	4	26	**47**	23	...	+	Ap. 100—0 m.
53	»	»	» »	1	1	4	**41**	37	16	...	.....	Nans. 0, 100—0 m.
54	»	64°58′	11°45′ (Da 17)	...	4	42	**50**	4	...	...	.....	„ , 350—210 m.
55	»	»	» »	...	(1)	(12)	(**37**)	(2)	(1)	...	.....	Ap. 150—75 m.
56	»	»	» »	...	...	17	**69**	12	2	...	.....	Nans. 0, 50—28 m.
57	»	64°58′	12°40′ (Da 18)	...	...	26	**59**	15	...	...	.....	„ , 130—0 m.
58	»	64°58′	13°25′ (Da 19)	...	2	11	**71**	22	1	1	.....	Ap. 80—0 m.

Nr.	Date	N. Lat.	W. Long.	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
59	2	66°10′	20°21′	...	1	**47**	38	12	2	...	+	Skálholt
60	9	66°10′	20°13′	...	...	18	**44**	35	2	...	+	»
61	»	64°00′	15°54′	...	6	41	**45**	8	...	...	.....	Hólar
62	12	66°03′	14°36′	...	...	**58**	42	...	...	...	+	Egg-net
63	»	65°30′	13°31′	...	...	3	46	**51**	...	...	+	»
64	13	66°16′	13°36′	..	...	12	**84**	4	...	...	c	»
65	»	66°10′	14°29′	...	...	(**31**)	(15)	...	...	..	c	Ap. 150 –20 m.
66	14	66°26′	14°50′	...	(2)	(34)	(**35**)	...	...	...	c	Hólar
67	»	66°25′	14°51′	...	1	39	**59**	1	...	...	cc	Horiz.-net
68	15	66°36′	16°18′	...	2	47	**50**	1	...	...	c	»
69	»	66°12′	18°15′	...	2	11	**66**	20	1	...	c	»
70	»	66°14′	17°28′	...	1	32	**65**	2	...	...	.....	Egg-net
71	18	59°41′	6°00′	...	(4)	(4)	(9)	(3)	(1)	...	c	Laura
72	22	66°36′	16°18′	...	3	**88**	8	...	1	...	c	Hólar
73	23	66°19′	20°38′	3	12	**78**	7	...	...	...	.....	Nans. 0, 190—75 m.
74	24	66°05′	21°14′	...	1	14	32	**53**	...	...	.....	Egg-net
75	»	66°24′	21°38′	...	8	**73**	16	3	...	...	.....	»
76	»	66°30′	22°25′	...	2	40	16	**42**	...	...	.....	»
77	25	66°19′	23°27′	...	16	**64**	13	7	...	...	.....	»
78	27	64°25′	22°53′	...	5	**48**	46	1	...	...	c	»
79	28	65°26′	24°17′	...	(20)	(**22**)	(6)	(3)	...	...	.....	Skálholt
80	29	64°00′	15°54′	. .	(7)	(28)	(21)	(**38**)	(4)	...	+	Hólar
81	30	63°46′	22°48′	...	5	38	**53**	4	...	...	.....	Egg-net
82	31	63°20′	20°49′	3	3	**94**	...	...	...	...	.....	Young-fish trawl, ca. 50 m. depth

but rich quantities were found almost everywhere in deep water, even very far down more than 500 m. under the surface. The temperatures here are very low, some of the deepest hauls are given below with temperatures prevailing in the corresponding depths (taken from the Bulletin mentioned).

No.	Station	Haul	Temperature		Quantities of *Calanus finmarchicus*
2	Da 3	Ap. 1600—500 m.	— 0·95°,	+ 0·41°	+
7	Da 4A	Nans. 0, 1600—500 m.	— 1·02°,	+ 0·17°	r
10	Da 5	» , 900—450 m.	ca. — 0·51°,	ca. + 1·00°	cc
19	Da 8	» , 500—280 m.	ca. + 0·10°,	ca. + 7·15°	cc
24	Da 9	Ap. 700—400 m.	ca. — 0·40°,	+ 0·80°	cc
30	Da 11	Nans. 0, 600—320 m.	ca. — 0·40°,	ca. + 3·32°	cc

It appears from these cases that in August *Calanus finmarchicus* may live in deep water in temperatures under + 1°. The Bulletin shows that more Calani are present in deep water than on the surface and our August table shows that the individuals are younger as we approach nearer to the surface and that males seem only to occur in deep water.

In May most of the *Calanus finmarchicus* are found near the surface (as Damas also points out), his conjecture that they descend deeper as they become older seems to be quite correct. On the other hand, the lower boundary for their occurrence in August must be moved deeper down than the 2° isotherm, where he puts it.

Nauplii occur at most of the stations but it is uncertain if they belong to *Calanus finmarchicus*. The occurrence of males and adult females in deep water justifies the conclusion that propagation is going on, even though it can only be slight to judge from the small numbers.

I can see no difference between the stages at the stations in colder water (St. Da 4 A, 10, 17, 18, 19) and those in warmer water (remaining stations), and as regards the quantities there is only to note that the stations Da 4 and Da 4 A are poorer than the others, though they are not the coldest.

From the southern waters we have so few samples in August that scarcely anything can be concluded from them. The very small Calani in Nos. 61 and 80 might perhaps have come from the east coast. Otherwise, it might be concluded that I and II are the commonest stages at the south of Iceland (No. 82). Off the westerly south coast, where the "Thor" was working in the last days of August, there were but few Calani in the plankton, those from No. 82 were from a several hours haul with the young-fish trawl. Samples taken by the "Hólar" at the Westman Islands on Aug. 3rd and 8th have only a few Calani or none. There are also but few samples from the western waters (77, 78, 79, 81), which seem to indicate that II is the predominating stage. There are 2 samples without Calani but with many Nauplii from Snæfellsnes collected on Aug. 21st and 25th by the "Skálholt".

To the north of Iceland we also meet with great quantities of *Calanus finmarchicus* in August, — at Cape North (No. 76) for example a 5 minutes haul with a net of 1 m. in diameter took over 200,000 specimens. There is on the whole the same rich pelagic life as in July: *Evadne Nordmanni*, *Temora longicornis*, jelly-fishes, Euphausidae and pteropods (*Spirialis*, *Limacina*) are predominant in addition to Calanus. The pteropods were lacking or were unimportant in July. Fish young were also taken in quantities. To ascertain what they were living on, I opened ten young of the cod and four of the haddock — in size all about 4—5 cm. — and examined the contents of their stomachs. All the cod contained almost exclusively *Calanus finmarchicus* and *Temora longicornis*, often in Thousands. The haddock were living partly on the same food, partly they seem partial to larvae of mussels and gastropods, of which a quantity were present. That Calanus and Temora are the main food of the cod has already been shown by G. O. Sars[1].

The herring fishery was still in full swing in August.

It is chiefly stage III which is predominant at the north of Iceland, No. 73 shows that the specimens in deep water are also here the larger.

The hydrographical conditions at North Iceland in August can be summarised as follows (Nielsen p. 21 et seq., section VIII): there is warm water fairly fresh from the surface to the bottom, which seldom is under 5° even deep down. A difference occurs however at the westerly north coast (especially Station 106 in Huna Deep), where cold and fresh (4·50°, 32·18 ‰) surface water was found, a result of the ice which had lain and was still partly present at North-West Iceland.

On the east coast of Iceland (Nos. 57, 58, 62—65) the conditions seem to be the same as those on the north coast: stage III is predominant; even where it is not in the majority it composes a great part of all the specimens.

Nielsen's section VIII (p. 19) shows, that the warm water from the north coast of Iceland keeps close to the land on the east coast, further to sea the cold water of the East Icelandic Polar Current is found at a small depth and there is only a thin layer of warmer surface water, which does not come from the Irminger Current. Our samples from the eastern waters mentioned above, except perhaps No. 57 (Da 18), must be taken to be from this warmer water coming from North Iceland.

In August we find all the waters round Iceland populated by *juniores*, amongst which stage II seems to be strongly represented to the south and south-east of Iceland, stage III north and east of Iceland. To the south and west of the island there seem to be but few *Calanus finmarchicus* in the waters, north and east there are many. The vertical hauls made show, that we find larger stages in deep water than at the surface, to these larger stages belong also adult males and females.

[1] Indberetninger til Departementet for det Indre fra Professor, Dr. G. O. Sars om de af ham i Aarene 1864—1878 anstillede Undersøgelser angaaende Saltvandsfiskerierne. Christiania 1879; p. 35.

September—October 1904

Material

No.	Date	N. Lat.	W. Long.	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
	Septbr.											
1	1	66°28′	22°00′	...	9	**62**	25	3	1	...	.....	Laura
2	»	66°30′	22°18′	...	(3)	(15)	(**24**)	(9)	(4)	...	+	Skálholt
3	9	64°44′	12°44′	...	(4)	(**7**)	(2)	...	...	...	.....	Laura
4	11	66°26′	14°30′	...	...	**93**	7	...	...	...	+	Hólar
5	12	66°33′	16°31′	...	3	**89**	7	1	...	...	+	»
6	13	66°12′	18°15′	...	7	**79**	13	1	...	...	+	»
7	18	»	»	...	...	33	**57**	5	4	1	c	»
8	19	66°33′	16°31′	...	1	**87**	12	...	...	...	.....	»
	Octbr.											
9	4	66°18′	23°12′	...	1	17	25	**30**	22	5	.....	Skálholt
10	5	63°08′	18°08′	...	...	(2)	(3)	(**6**)	(1)	(1)	.....	Laura
11	6	63°24′	20°05′	...	19	**37**	18	13	10	3	.. ...	»
12	»	64°00′	15°54′	...	3	15	23	**40**	17	2	.....	Hólar
13	12	66°12′	18°15′	...	...	**61**	24	10	2	3	.....	»
14	20	63°30′	24°10′	...	...	(11)	(**19**)	(4)	(1)	...	.....	Laura
15	»	66°12′	18°15′	...	1	**59**	31	8	1	...	.....	Hólar
16	21	66°26′	14°30′	...	(1)	(**56**)	(25)	(5)	(1)	...	.....	»
17	26	63°05′	18°40′	...	...	(10)	(**22**)	...	...	...	.....	Laura

As my material for these two months is so small I have included them together and also treat of the few observations for November at the same time.

From the southern waters we have but few samples, all for October (Nos. 10—12, 17), the more easterly three are remarkable for the small stages they contain. Somewhat more to the south, at 62°42′ N. L. and 18°16′ W. L. (the place is marked on the Chart by a point) I found whilst with the "Thor" a number of *Calanus finmarchicus* in the stages IV, V and VI, but the samples have unfortunately been lost so that I have not been able to count the specimens. Otherwise, the "Thor" found no *Calanus finmarchicus* on the way from here to Scotland, some of the stations are marked on the Chart. From the voyages of the "Laura" we have only No. 2 containing Calanus, and no Calanus were found in samples collected by the "Hólar" at Hrolaugseyar and Vestmannaeyar on Sept. 26th, Oct. 31st and Sept. 15th and 28th — the last two contain a number of Nauplii.

From the western waters we have only two samples (Nos. 9 and 14) containing small *juniores*. The samples of the "Skálholt" from Snæfellsnes (Sept. 18th with Nauplii, Sept. 27th, Nov. 10th) and from Staalbjærg Huk (Sept. 17th with Nauplii, Sept. 29th and Nov. 6th) were all without Calanus or with but single specimens. Plankton in addition to sample No. 9 was taken in Isa Fjord on Sept. 14th and Nov. 2nd but with no Calani.

At the north coast on the other hand, especially its eastern part, no small quantities of *Calanus finmarchicus* were still found in September and October. Gógurtá was in these two months the only spot where all the "Hólar's" stations (four in number) showed Calanus. From Cape North we have the following samples without Calanus: Sept. 14th (with Nauplii), Oct. 5th, Nov. 1st; from Skagatá Sept. 4th and 11th, Oct. 10th and 20th; from Rødehuk Oct. 12th (with Nauplii); from Langanes Septbr. 20th (with Nauplii), Oct. 11th and 23rd.

It is now stage II which is predominant on the north coast, especially in October. Calanus is thus larger than in August.

From the eastern waters we have practically no material. Three samples with no Calanus were collected at Papey on Sept. 7th, Oct. 6th and 31st.

What is most apparent in the conditions in the autumn is, that Calanus seems to be less developed in the south of Iceland than in the north. I can conceive of two explanations: the one, that these small Calani come from the east coast and thus have made the complete journey round the island, the other that this is a third generation, — mature specimens of both sexes were found indeed in deep water in June, so the idea is not quite so strange that a new generation should spring up in the warm Atlantic waters, in which as shown by GRAN development proceeds more rapidly than in colder waters.

From the winter months December, January and February there are no samples. The voyages of the "Hólar" and Skálholt" round Iceland cease towards the end of October and none of the samples from the winter voyages of the "Laura" contain *Calanus finmarchicus*. As it is of some interest to know what happens to this species in winter, I have examined some samples taken in Norwegian fjords by Dr. O. NORDGAARD of Bergen during winter months, and which have been kindly placed at my disposal by this scientist[1]. The samples are the following:

No.	Date	Place	♂	I	II	III	IV	V	VI	Nauplius	Mode of collection
1	24. I 1899	Kvænangen I	3	1	**81**	15	...	...	...	rr	0—5 m.
2	27. I „	Lyngen I	...	...	**76**	24	...	...	...	rr	0—115 m.
3	4. II „	Skraaven	4	3	**84**	9	...	...	...	rr	0—380 m.
4	7. II „	Ofoten II	5	4	**82**	9	...	...	...	.....	250—200 m.
5	6. III „	Henningsvær	5	**63**	23	7	2	...	...	.....	0—140 m.
6	16. III „	Tranödybet	1	**70**	24	5	...	...	...	+	0—100 m.
7	29. III „	Tysfjord	(2)	(**54**)	(15)	...	...	...	...	c	0—100 m.
8	19. IV „	Kvænangen	...	(65)	...	...	...	...	...	.....	0—90 m.
9	27. V 1897	56 miles S.W. of S Fuglø	1	9	**42**	38	8	2	...	.....	?
10	28. V 1900	Bergen coast	...	7	**83**	9	1	...	...	.....	3—6 m.

Except No. 10 these samples were all taken in northern Norway. We see that around the Lofotens, where Nos. 3—6 were taken, the adults were in the majority and propagation was probably already going on in the beginning of March, whilst more to the north (No. 9) in another year it had not yet begun.

From Nos. 1—4 we see that stage II seems to be the predominant winter stage. And from NORDGAARD's (l. c.) tables and text we learn that most often, though not always, the greatest quantities of *Calanus finmarchicus* were found in depths of 200—300 m.

Résumé

As it is only the spring months which give a large and constant maximum of mature *Calanus finmarchicus*, we must conclude with GRAN and DAMAS, that this species has its principal reproductive period at any rate in the spring and that the individuals die after propagating. We have seen that at this period the adults are found both at the surface and further down in deep water. I believe however that the spring is perhaps not the only reproductive period of *Calanus finmarchicus*, for the reason that we also find the adults of both sexes at other times of the year almost everywhere where fishing has been carried on in deep water. Is it possible that these live through the winter and only reproduce in spring? We do not know anything about it, but such a case is known

[1] O. NORDGAARD and E. JORGENSEN: Hydrographical and biological investigations in Norwegian fjords. Bergens Museum. Bergen 1905.

however of a freshwater copepod. G. BURCKHARDT[1] has noticed in *Diaptomus laciniatus*, that it was only 135 days after the first mature specimens were observed in the plankton that the first females provided with spermatophores were seen. Yet the maximum of mature specimens and the maximum of females with spores follow close upon one another. This would correspond to the condition in *Calanus finmarchicus* except that the adults of the new generation of this species would often have a much longer time than 135 days to wait, for example, from June or July to April. It cannot be denied that this sounds improbable.

To the south of Iceland are found great quantities of *Calanus finmarchicus* which seem to belong here, and in 1904 these waters were likewise the only true Icelandic waters where *Calanus finmarchicus* propagated. This propagation begins already in March and ends in June. In these months we find practically no Calanus to the north and east of Iceland. — As time goes on the old generation (the mature individuals) gradually die off and the new generation (*juniores*) grows up.

The latter is met with in April to the west of Iceland and in June on the north-west coast (we do not know the conditions in May), and it is only when it comes to July that we find great quantities on the north coast and in August there seem to be even more.

We have consequently some reason for concluding, that *Calanus finmarchicus* does not propagate on the west, north and east coasts of Iceland but that it is carried to these coasts by the Irminger Current northwards along the west coast and eastwards along the north coast. In agreement with this we find many *Calanus finmarchicus* to the south and west of Iceland in April but few to the north and east, whilst in August exactly the reverse is the case.

There is a striking parallel between these conditions as regards *Calanus finmarchicus* and the pelagic young of the cod. From Dr. SCHMIDT's remarks[2] on these we take the following (p. 72 et seq.): cod eggs are only found on the south (and west) coast of Iceland (in the spring), and in May and June the pelagic cod young could be observed on the same coasts and spread along the western part of the north coast.

The "Thor's" voyage in 1904 gives further information. As mentioned on p. 11, the waters on the north coast of Iceland were practically devoid of both *Calanus finmarchicus* and fish young in the beginning of June, and it was only on its western part that considerable quantities of Calanus were taken and the first cod young were found 45 miles still further to the west. And in July and August, when enormous masses of *Calanus finmarchicus* occurred in the waters north of Iceland the cod young were also common there. In August it was also found to the south of Langanes on the east coast.

The biological conditions are thus in perfect agreement with the phenomenon long known and proved with certainty by NIELSEN (l. c.), that Atlantic water from South Iceland goes west and northwards round the island. As shown by NIELSEN, this current plays an important economical part for Iceland, as not only is the climate partly dependent on it but assuredly the fisheries on the north (and east) coasts of Iceland also. We come here to a point which has been one of the aims I have had in view with this investigation, namely, the dependence of the great North Icelandic herring fishery upon the plankton organisms, especially *Calanus finmarchicus*. There are enormous quantities of herring to be found on the north coast of Iceland in July and August, we have seen a Norwegian steamer take several hundred barrels of herrings within a few hours, and whilst lying at anchor in a fjord we have seen the surface of the water literally living with herring, so closely packed together that a hook had just to be thrown into the shoal to catch one. It was shown above that *Calanus finmarchicus* forms a very essential part of the food of the herring, and it may therefore be considered as very probable, that the presence of the herring shoals is to some extent dependent on the presence of large

[1] Quantitative Studien über das Zooplankton des Vierwaldstättersees (Mittheil. d. Naturforsch. Gesellsch. Luzern. 3. Heft). Luzern 1900, p. 164.

[2] Fiskeriundersøgelser ved Island og Færøerne i Sommeren 1903. (Skrifter udgivne af Kommissionen for Havundersøgelser. Nr. 1. Kjøbenhavn 1904.)

quantities of *Calanus finmarchicus*, and therefore that it is in reality a hydrographical phenomenon which decides the question whether herring or no herring occur on the North Iceland coast. If there existed any available statistics of the herring fishery in these waters for several years (not only for the seines in the fjords, but also for out to sea), a comparison of the data with the currents and ice conditions would probably give interesting results; I believe it would show, that the herring fishery is in the first instance dependent on the Irminger Current, the warm oceanic current which brings the plankton organisms spawning in the south with it and most important: *Calanus finmarchicus*.

Towards autumn we find that the quanties of *Calanus finmarchicus* at the surface decrease. They have now mostly reached stage II and if we may conclude from Dr. NORDGAARD's material from the Norwegian fjords, they pass the winter in this stage in deep water and then when the spring comes they rise to the surface to undergo the last stage of metamorphosis.

But how is the stock of *Calanus finmarchicus* in the waters south of Iceland renewed? Does it renew itself or do the young, as DAMAS supposes, come from the waters round the Færoes? And what comes of all the specimens of this species which even in October populate the waters at North Iceland — where do they reproduce next year?

These important questions could not be answered by means of the present material.

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Plate I.

Plate I. April–May 1904.

● means many *Calanus finmarchicus*.

● » few » »

⊙ » no » » at the surface.

⊙ » » » » in deep water.

I » that stage I is predominant at the surface.

II » » » II » » in deep water.

The black numerals annexed refer to the table for April, the blue ones to the table for May. Where no numerals occur, a black dot means April, a blue one May.

( ) means that the sample has been taken with coarser gauze than No. 20.

? » that the sample did not contain 100 specimens.

□ » that the sample is from 1905.

N » many Nauplii at the surface.

N » » » in deep water.

GRØNLAND
ISLAND
Ísafjord
Húna-Bugt
Skagafjörd
Eyjafjörd
Langanes
Kollomuli
Seydisfjord
Rödefjord
Snæfellsnes
juniores
Faxe Bugt
Reykjanes
Ingolfs Höfde
Hrolaugseyar
Vestmannaeyar
Papey

Plate II.

Plate II. June–July 1904.

● means many *Calanus finmarchicus.*

• » few » »

⊙ » no » » at the surface.

⊙ » » » » in deep water.

I » that stage I is predominant at the surface.

II » » » II » » in deep water.

The black numerals annexed refer to the table for June, the blue ones to the table for July. Where no numerals occur a black dot means June, a blue one July.

( ) means that the sample has been taken with coarser gauze than No. 20.

? » that the sample did not contain 100 specimens.

N » many Nauplii.

Ísafjord
Hana-Bugt
Skagafj.
Gogurtá
Langanes
Kollumúli
Seydisfjord
Rödefjord
Snæfellsnes
Faxe Bugt
Reykjanes
Vestmannaeyar
Ingolfs Höfde
Hrolaugseyar
Papey

Plate III.

Plate III.
August–September–October 1904.

● means many *Calanus finmarchicus.*

• » few » »

⊙ » no » » at the surface.

⊙ » » » » in deep water.

I » that stage I is predominant at the surface.

II » » » II » » in deep water.

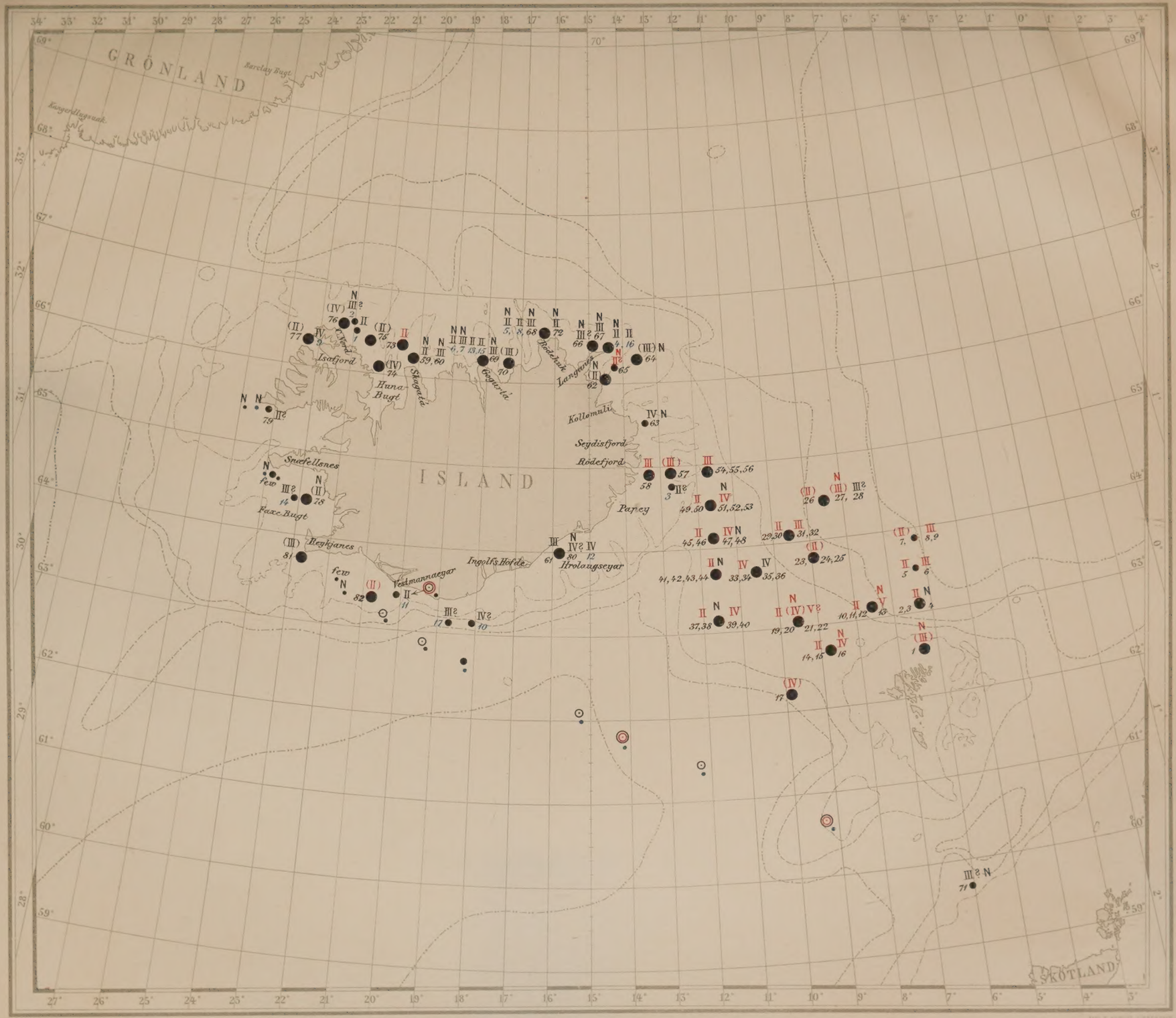
The black numerals annexed refer to the table for August, the blue ones to the table for September—October. Where no numerals occur, a black dot means August, a blue one September—October.

( ) means that the sample has been taken with coarser gauze than No. 20.

? » that the sample did not contain 100 specimens.

N » many Nauplii at the surface.

N » » » in deep water.


GRÖNLAND
Barclay Bugt
Kangerdlugssuak
ISLAND
Isafjord
Huna Bugt
Skagafjord
Eyjafjord
Rodebak
Langanes
Kollumuli
Seydisfjord
Rödefjord
Papey
Snefellsnes
Faxe Bugt
Reykjanes
Ingolfs Höfde
Westmannaeyar
Hrolaugseyar
SKOTLAND
Kilometer
naut. miles
1:6 000 000
200 Meter
600
1000
2000